
A FUZZY MADM METHOD FOR KEY SECTOR IDENTIFICATION: THE CASE OF INDONESIA

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ABSTRACT

Conventionally, the identification of a key sector of an economy is always associated with the measurement of the intersectoral linkages, in which a key sector is defined as a sector that provides an above-average contribution in inducing the whole economy to grow. Unfortunately, the existing methods for key sector identification have also some conceptual limitations. Due to the limitations inherent in existing methods, an alternative approach, providing more realistic, appropriate meaning and broader perspectives in interpreting the notion of a key sector, is desirable. The main objective of this work is to provide methodological improvements over previous works in examining the key sectors of an economy, by proposing an alternative approach involving the application of fuzzy set theory in the field of multi-criteria decision making. The modeling of the key sector identification problem as a fuzzy-MADM problem enables the consideration of other relevant criteria. The application of fuzzy sets theory makes possible the assessment of qualitative and imprecise information, which is very often found but is difficult to solve in real life decision making problems. When applying data to Indonesia, the new approach has successfully identified key sectors the Indonesian economy which vary over time under study.

Key words : fuzzy MADM, interindustry linkage, key sector

1 INTRODUCTION

One of the most important tasks in planning for the economic development of developing countries is being able to promote different economic sectors appropriately to solve social, economic and other related problems. A sound and appropriate development strategy, focusing on the promotion of the efficient and prospective production sectors, is therefore, required for achieving the intended development goals. To achieve the best possible result and optimal allocation of resources, it is recommended that the investment should be more concentrated in the sectors with a high degree of linkages [Hazari, 1970]. This suggestion is strengthened by the fact that the process of economic development is often driven only by a small number of so-called "leading" or "key" sectors, that will provide a leading

role for a sustained economic growth and thus reduce the probability of slowdown leading to an economic crisis.

As the development approach shifts from focusing on growth towards sustainable development, the relevancy of the over simplified conventional methods becomes questionable. Given the limitations inherent in the existing methods, a more appropriate method for defining and identifying key sector is desirable to resolve the deficiencies and thus provides more realistic meaning and broader perspectives, particularly with regard how to define and identify the key sectors of an economy.

The main objective of this research is to propose a new alternative approach as the resolution of the weaknesses of the conventional methods for defining and identifying the key sectors of an economy. The main focus is how to develop a decision aid to help in interpreting the notion of the key sectors of an economy that appear best

suited to the sectoral promotion policy, particularly in the case of developing countries. The proposed approach should provide a new perspective and broader spectrum by taking into account all the relevant criteria for delivering a more realistic approach and more satisfactory results than the existing methods have so far employed and supplied.

2. THEORETICAL BACKGROUND

The linkage approach provides a valuable insight into the interdependence of different sectors of an economy. It is very useful if it is directed towards the empirical identification of key sectors. There is general recognition of the importance of linkages that mainly directed towards the identification of so-called "strategic" or "key" sectors of the economy. Unfortunately, until recently, there was neither a standardizing method nor a generally accepted consensus regarding the ways in which key sectors should be defined and identified [Cella, 1984]. Obviously, the definition and the determination of the key sectors of an economy can be presented from different point of views.

Until recently, linkage approach become the most commonly accepted method for the determination of the key sectors of an economy. The empirical results from the identification of the key sectors of the economies of developing countries revealed that the existing methods seem to be less satisfactory and to suffer from some conceptual limitations. It is often argued that the linkage approach is too simple and too crude as an empirical method for the identification of the key sectors of an economy, due to inherent limitations that can seriously affect the empirical results. The drawbacks are mainly caused by the difficulties and the inappropriateness in interpreting the notion of a key sector as an above-average contributor to the economic growth. One of the main drawbacks of

these conventional approaches is the failure to deal with the conflicting objectives of development and undermine the efforts to achieve different development goals simultaneously. It was clear that key sectors should neither be defined nor identified uniquely using the general method, but it should be designed to meet with the requirements for achieving the intended development goals.

The concept of sustainable development is multi-dimensional and still being developed, constantly being revised and refined. Until recently, there has been no single concept of sustainable development found, as the economic situation, social systems and ecological conditions differ widely among countries [Köhn and Gowdy, in: Köhn, Gowdy and van der Straaten, 2001]. The complex interaction between economic development and environmental concern also indicates that the concept of sustainable development is fuzzy in nature and difficult to be derived operationally.

It has been widely recognized that most of the decisions made in the real world taken place in an environment in which the goals and constraints, due to their complexity, are not known precisely and thus the problem cannot be exactly defined or precisely represented in a crisp value. To deal with the kind of qualitative, imprecise information or even ill-structured decision problems, Zadeh, (1965) suggested employing fuzzy set theory as a modeling tool for complex systems that can be controlled by humans but are hard to define exactly.

In a real-world decision situation, the application of the classical MADM method may face serious practical constraints, due to the criteria perhaps containing imprecision or vagueness inherent in the information. The presence of fuzziness or imprecision in a MADM problem will obviously increase the complexity of the decision situation in many ways. Fuzzy or qualitative data are operationally more difficult to manipulate than crisp data, and certainly increase the computational requirements in particular during the process of ranking when searching for the preferred alternatives (Chen and Hwang, 1992). As decision making becomes more involved in

both humanistic and complex systems, fuzziness become the prevalent phenomena for describing these systems. The attitude towards uncertainty and subjectivity inherent in human behavior during the process of decision making has led to the new area of study which applies fuzzy sets theory in the decision making area. This is known as Fuzzy Multi Criteria Decision Making (Fuzzy-MCDM). The main feature of this approach is that the imprecision inherent in the qualitative information can be formalized by applying fuzzy sets theory. The fuzzy-MCDM methods have basically been developed along the same lines as conventional MCDM methods, but are designed with the help of fuzzy set theory to deal specifically with MCDM problems containing fuzzy data (Zimmermann, 1996; Chen and Hwang, 1992; Carlsson and Fuller, 1996). The introduction of fuzzy set theory to the field of decision making provides a consistent representation of qualitatively or linguistically formulated knowledge in such a way that still allows the use of precise operators and algorithms. The application of fuzzy set theory will facilitate the formulation of a complex, ill-defined and subjectively perceived decision problem in a more appropriate manner. It also enables the representation and adequate processing of the vagueness or imprecision into the formal decision model in such a way that there is no simplification, but an intellectually and scientifically acceptable manner (Zimmerman and Zysno, 1985). In principle, a fuzzy multi-criteria decision method should include the process of identifying, measuring and combining criteria of alternatives to create a conceptual model for decision and evaluation in a fuzzy environment (Romelfanger, 1988).

There are many variations of the existing fuzzy MADM method, depending upon the theoretical basis used for modeling.

These approaches are basically developed along the same lines as the classic methods. Fuzzy MADM methods differentiated into two main phases. The first phase is generally known as the rating process, dealing with the measurement of performance ratings or the degree of satisfaction with respect to all the attributes of each alternative. The aggregate rating, indicating the global performance of each alternative, can be obtained through the accomplishment of suitable aggregation operations of all the criteria involved in the decision. The second phase, the ranking of alternatives, is carried out by ordering the existing alternatives according to the resulted aggregated performance ratings obtained from the first phase.

To deal with such problems, the fuzzy data are generally transformed into crisp data, thus enabling the aggregation of all the criteria involved in the judgment of each decision alternative to be carried out efficiently. A triangular or trapezoidal fuzzy number is usually used to express the decision maker's perception of alternatives' performances with respect to each criterion. An aggregation process is then carried out to provide the overall judgments about the degree of satisfaction or rating of all the criteria with respect to each decision alternative. The aggregation operators suitable for this operation may vary from t-norm, t-conorm or averaging operators, depending on the context of the decision situation and the subjective preferences of the decision maker (Zimmermann, 1996).

The ranking of the existing alternatives is commonly accomplished on the basis of their achievement in satisfying the overall objective, which is generally associated with the global aggregated value or utilities of the respective alternatives. The process of ranking may result in a fuzzy as well as crisp solution to the problem, depending on the method to be applied. If the final judgment of aggregated value is expressed crisply, the ranking of alternatives does not pose any particular problems. On the contrary, the presence of fuzzy utilities will make the ranking process more difficult to be carried out.

In some aspects, the development of fuzzy MADM have similarities with the classic MADM model, for instance, in the formulation and construction of decision problems. The specific feature which differentiates this model from the classic MADM method lies at the stage of information processing, in which has to deal with both quantitative as well as qualitative data. To deal with imprecision or vagueness in the decision data, fuzzy set theory is applied to facilitate the information processing.

The fuzzification of input data and an aggregation process using a fuzzy rule base and an inference system followed by defuzzification of output are the special characteristics of information processing for producing plausible results. As the information processing has been accomplished, the process of the ranking of the alternatives can be carried out without significant problems. The main phases of the development of a fuzzy MADM method is presented in Figure 1.

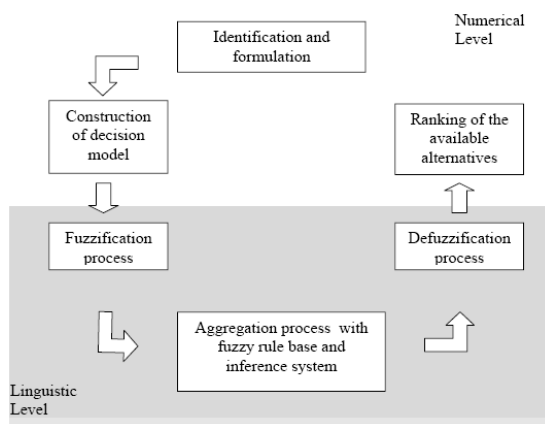


Figure 1: The main phases of the development of a fuzzy MADM method

3. RESEARCH METHOD

Adopting the concept of sustainable development, the notion of key sectors will refer to a sector or a set of sectors of the economy that satisfy the predetermined criteria associated with the development goals to be realized. Accordingly, key sector identification can be seen as a problem of selecting or ranking of sectors that meet those predetermined criteria that associated with a multi-criteria decision making problem. The nature of such a decision becomes more complex, due to the existence of conflicting objectives, a hierarchical structure of criteria and the presence of qualitative, as well as imprecise information. The proposed method is aimed at resolving the limitations of the existing conventional methods and, more importantly, must be able to deal with the imprecision inherent in human judgment.

The proposed model is developed through the extension of the existing concept of the key sector, by introducing some new relevant criteria associated with the intended development goals in the model. Instead of exclusively focusing on a mechanical manner, by quantifying the linkage effects, the notion of the key sector is newly defined, allowing the consideration of other relevant or strategic criteria related to economic, social and environmental aspects believed to play a crucial role in determining the sector's performance. These classes of criteria can serve as the basis for the derivation of the relevant basic measurable criteria that are very useful for the operationalization of the concept of key sector.

The application of fuzzy sets theory in the field of multi-attribute decision making is aimed at developing a more appropriate approach for key sector identification to deal with multiple goals of development and inherent imprecision. It is expected that the fuzzy multi-attribute decision making approach developed in this work could give a broader, more comprehensive perspective and produce more realistic meaning than the existing methods so far employed.

By considering the intended development goals, the proposed method will be applied for the

empirical identification of the key sectors of an economy, with the case of Indonesia. The selection of strategic criteria used in this study is based on findings of previous studies and a-priori assumptions about factors that are most likely to affect the decision. Although it can be carried out at any level of sector aggregation, the assessment of quantitative and qualitative information regarding criteria responsible for key sector determination is carried out at the higher aggregated level of 26 sectors. A comprehensive appraisal of key sectors, based on a lower level of sectoral aggregation, is beyond the scope of the present study.

4. RESULT AND DISCUSSION

4.1. The Proposed Approach: A Fuzzy MADM Model

In the case of the relevant criteria referred to the intended goals to be realized, the derivation of the criteria will pose no any particular problem. In the case of the criteria could not be directly determined, it will be derived through operationalization of the available goals embodied in the notion of key sectors of an economy. The derivation into measurable basic indicators from the available goals should contain all the criteria that are considered to have the relevancy to the evaluation purposes.

The derivation of the operational variables of sustainable development concept results in a set of fourteen basic criteria associated with technological, economic, social and environmental aspects. The technological aspect will provide an indication of whether the technology employed for the production is appropriate, efficient and strengthens the economic structure, as indicated by its backward and forward linkages. The economic aspects are represented by the share of the GDP, the growth rate of the GDP, foreign earnings, net trade ratio

and productivity. Employment coefficient, employment share, income distribution, income level and regional development together construct the social indicator. Finally, there is the environmental perspective, indicating the sustainability of the respective sector expressed in terms of environmental threat and resources degradation. These basic indicators, embodied in the notion of key sectors, serve as a basis for the performance evaluation of each sector. However, the choice of the relevant criteria to be considered is still open that may be country-specific and vary over time. The derived criteria would depend on many factors, such as the urgency of the problems or goals to be achieved, the availability of resources, the development strategy to be pursued and, more importantly, the macro-economic environment, including the stage of a country's development.

The identification of key sectors can then be structured in a hierarchy of criteria corresponding to stepwise operationalization of the decision criteria into measurable attributes. The hierarchy of attributes used for the definition of the key sectors of an economy according to the new approach as shown in Figure 2.

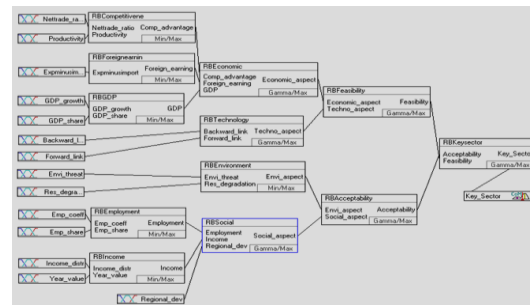


Figure 2. The hierarchy and operationalization of key sector identification

It illustrates that the process of key sector identification consist of several levels. At the first level is the global or ultimate objective “**key sector**” indicating the aggregated achievement of four main criteria: social, economic, environmental and technological aspects. Each of these main criteria then should derived further into measurable sub-attributes at the lower levels. All of these basic criteria form a hierarchy

defining the structure of decision problem associated with the process of the key sector identification of an economy.

4.2 Empirical Identification of Key Sectors of the Indonesian Economy

The adoption of the concept of sustainable development in the alternative approach implies that the notion of a key sector should also embody the characteristics corresponding to economic, social, technological and environmental aspects. Applying the developed approach to defining and identifying the key sectors of an economy, recent work has tried to rank the aggregated 26 sectors of the Indonesian economy according to their degree of achievement in satisfying key criteria. Using input-output data from 1990 and 1995 for Indonesia and by considering all the key criteria associated with the intended development goals, including their importance, the sectoral ranking of the Indonesian economy can be summarized in Table 1.

The application of a fuzzy-MADM approach for key sector identification can successfully identify the key sectors of the economy, which comprise primary, secondary as well as tertiary sectors. Evaluating the ranking of sectors of 1990 and 1995, there are some interesting features can be identified.

Some key sectors are identified for 1990, comprising primary, secondary and as well as tertiary sector. Food crops, livestock and oil and gas mining can be attributed to key sectors of the primary sector. Four out of eleven sectors qualify as key sectors belonging to the secondary sector, comprising oil and gas industry, food industry, textile industry and chemical industry. Construction, trade, hotel and restaurant, transport and communication are key sectors from the tertiary or service sectors. These sectors

together play a very significant role in the economy that accounted for 68.45 percent in terms of GDP and 72.28 percent in terms of employment.

Table 1. The key sectors of the Indonesian economy, 1990 and 1995

No	Sector	1990			1995		
		Crup value	Rank	Logprouctio	Crup value	Rank	Logprouctio
Primary sector							
1	Food crops	0,79927	1	Satisfactory	0,79927	5	Satisfactory
2	Other agriculture	0,21889	10	Slightly satisfactory	0,21889	11	Less satisfactory
3	Livestock	0,79900	4	Satisfactory	0,55926	15	Less satisfactory
4	Fishing	0,23076	15	Slightly satisfactory	0,26828	19	Slightly satisfactory
5	Minerals	0,51136	13	Slightly satisfactory	0,27772	18	Slightly satisfactory
6	Oil and gas mining	0,79527	2	Satisfactory	0,51000	17	Less satisfactory
7	Metal and non metal mining, quarrying	0,79527	3	Less satisfactory	0,20094	20	Less satisfactory
Secondary sector							
8	Oil and gas industry	0,79416	6	Satisfactory	0,73077	7	Satisfactory
9	Food industry	0,75000	3	Satisfactory	0,28284	2	Very satisfactory
10	Textile industry	0,75000	3	Satisfactory	0,75000	4	Satisfactory
11	Wood industry	0,25000	9	Less satisfactory	0,25000	12	Less satisfactory
12	Paper industry	0,20000	14	Less satisfactory	0,26076	8	Less satisfactory
13	Chemical industry	0,79218	5	Satisfactory	0,73078	6	Satisfactory
14	Non-metal mineral industry	0,20000	12	Less satisfactory	0,20000	14	Less satisfactory
15	Non-metal mineral industry	0,20000	14	Less satisfactory	0,20000	14	Less satisfactory
16	Metal industry	0,20000	11	Less satisfactory	0,75000	4	Satisfactory
17	Other industry	0,20000	12	Less satisfactory	0,20000	14	Less satisfactory
Tertiary sector							
18	Construction, gas and water	0,20000	14	Satisfactory	0,28014	16	Less satisfactory
19	Communications	0,75000	3	Satisfactory	0,75000	4	Satisfactory
20	Trade	0,75000	2	Satisfactory	0,75000	1	Satisfactory
21	Hotel and restaurant	0,75000	3	Satisfactory	0,75000	3	Satisfactory
22	Transport and telecommunications	0,75000	3	Satisfactory	0,28211	4	Very satisfactory
23	Finance	0,20000	10	Less satisfactory	0,75000	1	Satisfactory
24	Government and public services	0,20000	12	Less satisfactory	0,20000	4	Less satisfactory
25	Other services	0,20000	14	Less satisfactory	0,20000	9	Less satisfactory
26	Unspecified sectors	0,29928	17	Less satisfactory	0,79928	20	Less satisfactory

Applying the data for 1995, a slightly different result is obtained. Nine of eleven previously identified sectors still maintain their roles as key sectors of the economy. These sectors comprise food crops as the only key sector from primary sector, followed by oil and gas industry, food industry, textile industry and chemical industry as key sectors from the secondary sector and construction, trade, hotel and restaurant and transport and telecommunications as key sectors from the tertiary sector. Two primary sectors, namely livestock and oil and gas lose their role as key sector, and at the same time, metal goods industry and finance emerge as new leading sectors of the economy. The role played by the identified key sectors of 1995 has increased to 72.34 percent in terms of production, but has decreased to 69.59 percent in terms of employment. The shift of key sector from primary to secondary and tertiary sectors is accompanied by increasing productivity indicated by rising contribution to national GDP and decreasing number of labors involved.

The primary sector, such as food crops, qualifies as a key sector of the economy which can

mainly be attributed to its role in providing a great number of employment opportunities, as a source of income for the most needy people and also contributing to a moderate level of the GDP. The results clearly meet with the intuitive expectation corresponding to a "high" contribution in solving the increasing unemployment problem. The agricultural sector, which until recently was one of the most labor-intensive sectors of the economy, is the biggest contributor for employment opportunities for the unemployed people. Food crops provided 41.5 percent and 38 percent of the total employment in Indonesia for 1990 and 1995, respectively. Indeed, in terms of other criteria, such as productivity, foreign earnings or linkage effects, these sectors have an inferior performance, but these can be balanced by allowing some trade-off with the relative better performances in employment distribution of income and the maintaining of regional development. This role is very important to be considered in particular for this country, where an acute unemployment problem persists and disparity in the levels of development between regions/provinces still exists.

As expected, most of the key sectors of the Indonesian economy belong to the industrial sectors, comprising the oil and gas industry, the food industry, the textile industry and the chemical industry, and the metal goods industry. These sectors have similarities in terms of high linkage effects, both for backward and forward linkages, experiencing high growth rates far above the average of the economy, providing a major contribution to foreign earnings and operating with higher productivity than other sectors in the economy. Key sectors from the secondary sector were responsible for more than 33 and 35 percent of the GDP both in 1990 and 1995, respectively, accompanied with the increasing the number of sectors eligible as key sectors

from four to five sectors. The food industry itself plays an extraordinary role, producing almost 12 percent of the GDP in 1995, which can be attributed to the highest contribution from a single sector of the economy.

Conducive and favorable macro-economic conditions during the period under study were the major reason for high and sustained growth rates experienced by the industrial sectors. The industrial sectors have become the major engine of development in Indonesia as documented by their contribution to the foreign earnings and to increasing productivity. These superior performances have certainly contributed to the better results of the global assessment indicating their achievement in satisfying the criteria of key sectors. The spectacular increase in manufacturing exports can be attributed to the higher competitive attainment of the respective sector over their rivals in international markets. Resource-based and labor-intensive industrial sectors, such as the oil and gas, the food and textile industries, as expected, have played a leading role in expanding exports. These facts clearly justify the a priori assumption that, as a resources and labor-abundant country, Indonesia has a comparative advantage in the resource-based and labor-intensive sectors. However, it should be noted that the competitiveness of labor is particularly focused on low-skill labor, that is only suitable for supporting the development of light industry. The abundance of resources endowment also provides additional advantages for the resource-based products, such as oil and gas, food and other related industries. The crucial role played by these sectors is expected to be continued in the near future through the sustained growth as experienced in the past years in concurrence with the decreasing of the contribution of the primary sectors.

From the tertiary sector, construction, trade, hotel and restaurant, communications and transportation are among those identified as key sectors of the economy. Reducing trade barriers, and increasing product competitiveness has certainly led to the high performance of the trade sector mainly in contributing to the increasing share of the GDP, employment and

foreign earnings. The contribution of the trade sector to the GDP accounted for 8 percent in 1995, which simultaneously contributed to more than 15 percent of employment. Therefore, the trade sector can be attributed to the second biggest contributor to employment of the Indonesian economy. The qualification of hotel and restaurant, transportation and communication as key sectors of the Indonesian economy is believed to be due to the positive effects of the increasing income of the population and the blossoming of the world tourist industry.

Obviously, the ranking of sectors has slightly changed over the period under study, reflecting the structural change occurring in the Indonesian economy. As the economy becomes more diversified, the role of particular sectors in contributing to the GDP, employment, foreign exchange and other criteria may change. Moreover, the shift of key sectors of the economy may also be a response to the changing priorities of the development objectives and changing on international environment.

The results also reveal that agriculture and sectors strongly linked to agriculture, such as food processing, are generally associated with a high ratio of jobs per unit of output. However, one cannot always assume that the sectors that stimulate a great amount of employment per unit of output are those that can maximize job creation for a given amount of capital. The results of the study also reveal that many modern industrial sectors are associated with low job creation per unit of capital. Sectors such as chemical, basic metal and metal goods are ranked among the worst in terms of generating employment capability.

In terms of distributive performance, it is indicated that textiles, chemicals and the

metal goods industry and service sectors are associated with a high degree of income distribution. Although labor intensity is usually associated with an even distributive performance, this is not always the case. Moreover, a fairer distribution of income does not necessarily mean that the people engaged in these sectors are better off, due to the low level of wages received by the employed people. As the economy becomes more open and diversified, it is reasonable to expect that the sectoral allocation of production would alter in favor of those sectors of which Indonesia enjoys a comparative advantage, such as labor-intensive and resources-based. Thus, when promoting labor-intensive sectors, this should be accompanied by efforts to provide employment opportunities offering more productive and better-paid jobs.

5. CONCLUSION AND IMPLICATION

The proposed fuzzy MADM approach represents a new, promising and challenging research area with a wide field of potential applications including the economic field. The results presented in this work show that the application of the fuzzy-MADM approach can rationally define and effectively identify the key sectors of an economy. Contrasting with the classic methods, the proposed approach provides a more realistic approach and broader perspective in interpreting the notion of key sectors. It allows the consideration of all relevant criteria corresponding to the intended goals, some of which might be excluded in the conventional approach, and thus provides a more reliable estimate about the decision situation. It also makes it possible for the decision maker to consider trade-off between criteria, leading to rational judgment and a more satisfactory result than the existing methods so far employed.

The findings obtained from this study are very valuable in establishing the strategic framework for sectoral promotion policies, which should be adopted by the governing body responsible for development planning. In the case of the Indonesian economy, the results of the

empirical identification of the key sectors reveal that key sectors cannot be exclusively associated with modern industrial sectors. It also suggests that there might be a conflict in a development strategy that simultaneously attempts to maximize all the development goals, and it thus underlines the need for considering trade-off between objectives in order to arrive at a rational and acceptable compromise solution.

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